Jet Propulsion Laboratory
California Institute of Technology

Multi-Frequency Radar Retrieval of Snowfall Microphysics

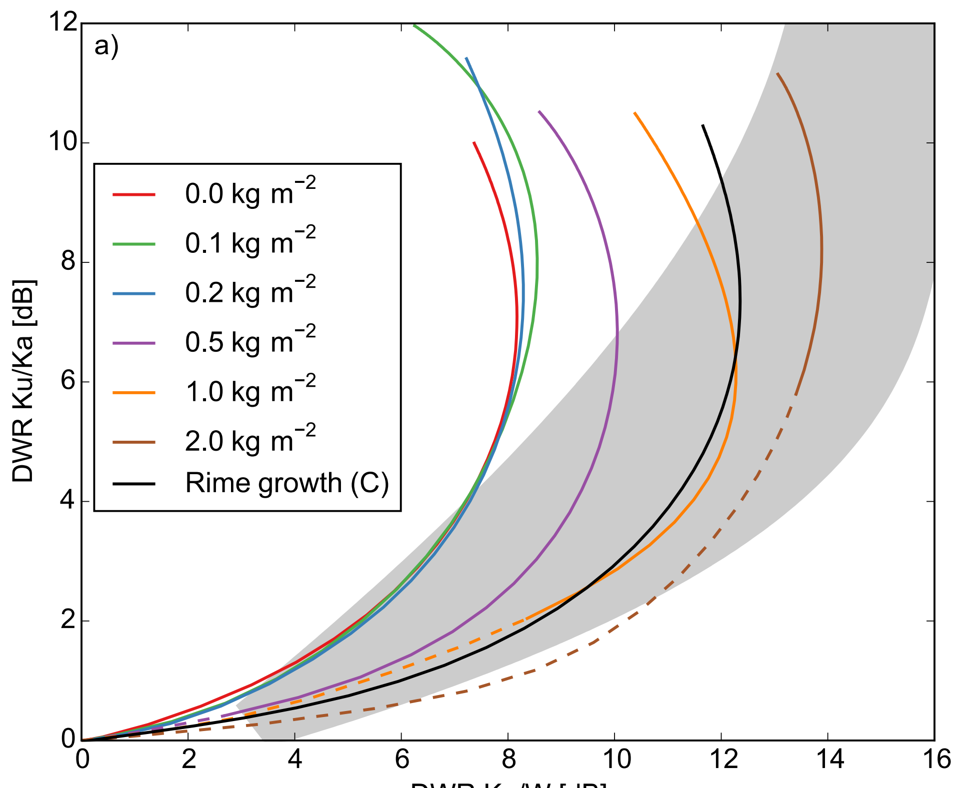
Jussi Leinonen

With contributions from:

Matthew D. Lebsock, Ousmane O. Sy, Simone Tanelli, Brenda Dolan,
Randy J. Chase, Joseph A. Finlon, Dmitri Moisseev, Annakaisa von Lerber

Multi-frequency retrievals

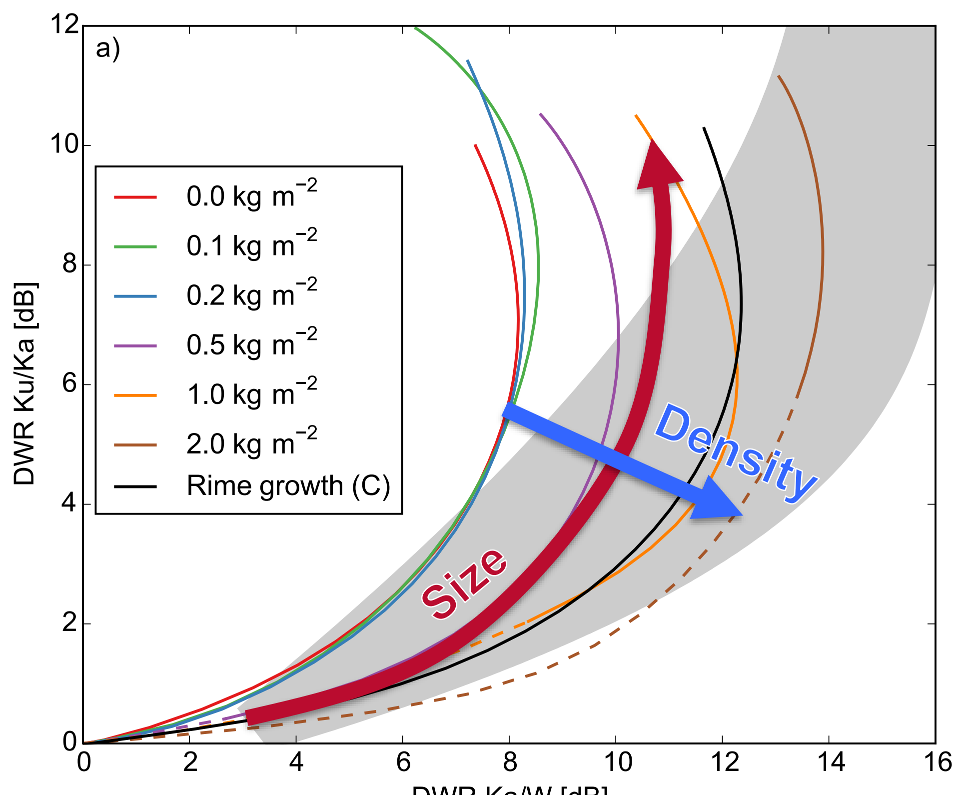
- Single frequency: water *content*
- Dual-frequency: hydrometeor *size*
- Triple-frequency: snow *density*



Leinonen and Szyrmer (2015)

Multi-frequency retrievals

- Single frequency: water *content*
- Dual-frequency: hydrometeor *size*
- Triple-frequency: snow *density*

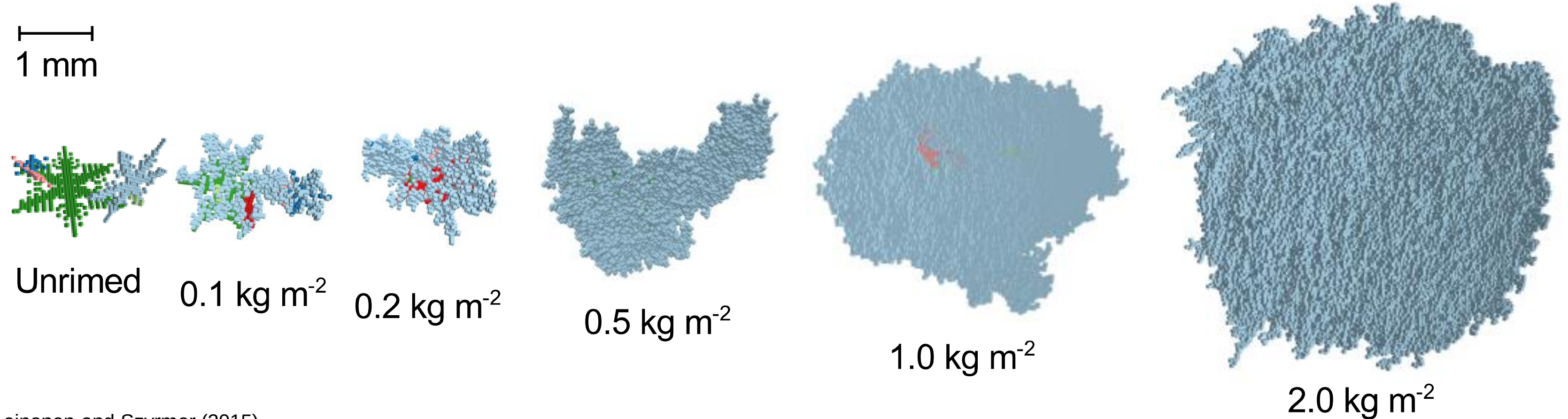


Leinonen and Szyrmer (2015)

Multi-frequency retrievals

Now available:

- Triple-frequency data from campaigns
- Snow scattering databases with variable density



Leinonen and Szyrmer (2015)

Algorithm

$$\mathrm{E}[\mathbf{x}|\mathbf{y}] = \int \mathbf{x}\, p(\mathbf{x}|\mathbf{y})\, \mathrm{d}\mathbf{x} = \frac{1}{p(\mathbf{y})} \int \mathbf{x}\, p(\mathbf{y}|\mathbf{x})\, p(\mathbf{x})\, \mathrm{d}\mathbf{x}$$

Measurement:

$$\mathbf{y} = \begin{bmatrix} Z_{\mathrm{dB,Ku}} \\ \mathrm{DWR}_{\mathrm{Ka/W}} \\ \mathrm{DWR}_{\mathrm{Ku/Ka}} \end{bmatrix}$$

State:

$$\mathbf{x} = \begin{bmatrix} \ln\ N_0 & \ln\ \Lambda & \ln\ \alpha \end{bmatrix}^T$$

$$N(D) = N_0 \exp(-\Lambda D)$$

$$m(D) = \alpha D^{\beta}$$

Algorithm

$$\mathrm{E}[\mathbf{x}|\mathbf{y}] = \int \mathbf{x}\, p(\mathbf{x}|\mathbf{y})\, \mathrm{d}\mathbf{x} = \frac{1}{p(\mathbf{y})} \int \mathbf{x}\, p(\mathbf{y}|\mathbf{x})\, p(\mathbf{x})\, \mathrm{d}\mathbf{x}$$

Measurement:

$$\mathbf{y} = \begin{bmatrix} Z_{\mathrm{dB,Ku}} \\ \mathrm{DWR}_{\mathrm{Ka/W}} \\ \mathrm{DWR}_{\mathrm{Ku/Ka}} \end{bmatrix}$$

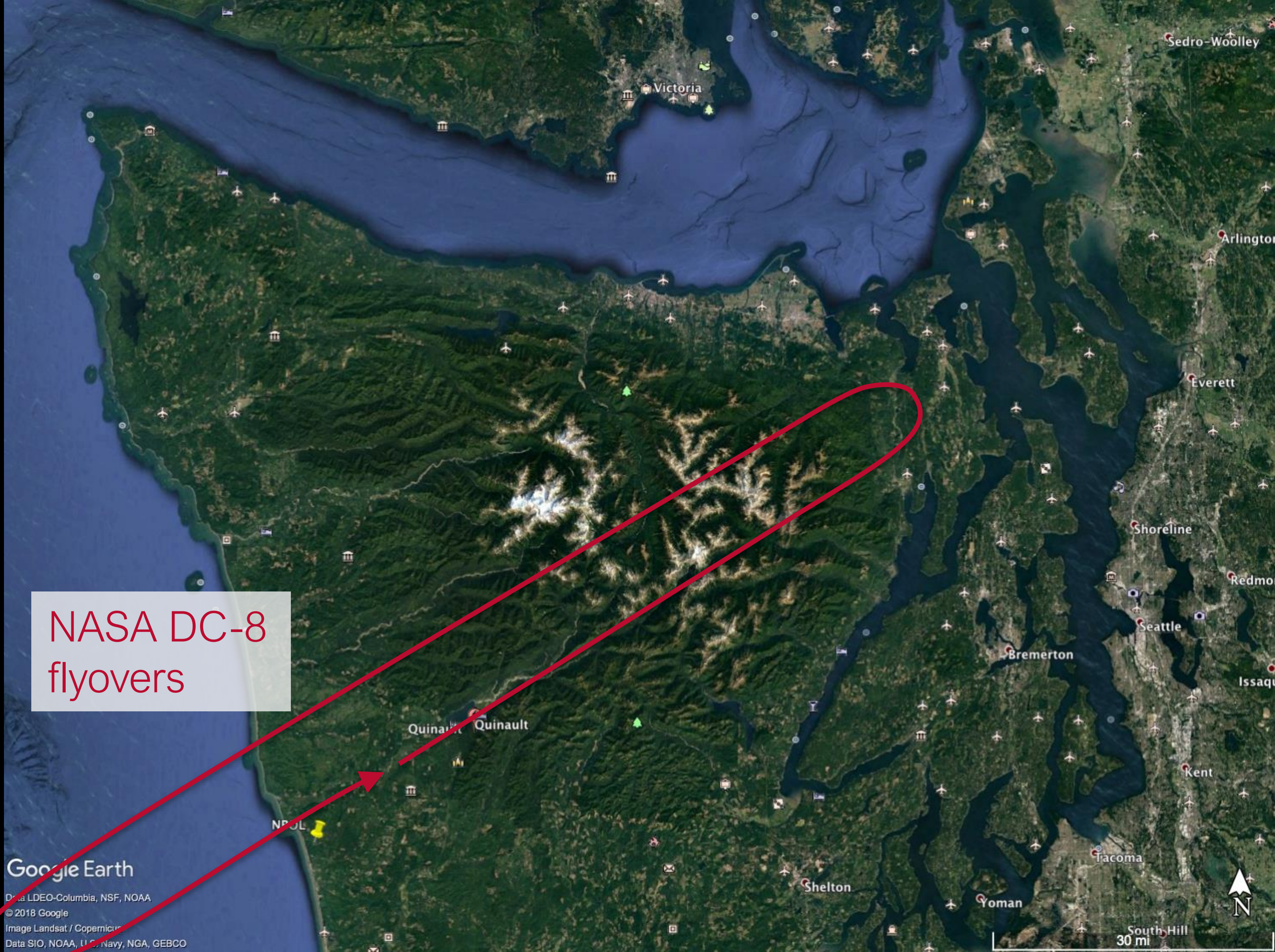
Forward model +
Measurement error

State:

$$\mathbf{x} = \begin{bmatrix} \ln N_0 & \ln \Lambda & \ln \alpha \end{bmatrix}^T$$
$$N(D) = N_0 \exp(-\Lambda D)$$
$$m(D) = \alpha D^{\beta}$$

A priori probability
(from field measurements)

OLYMPEX



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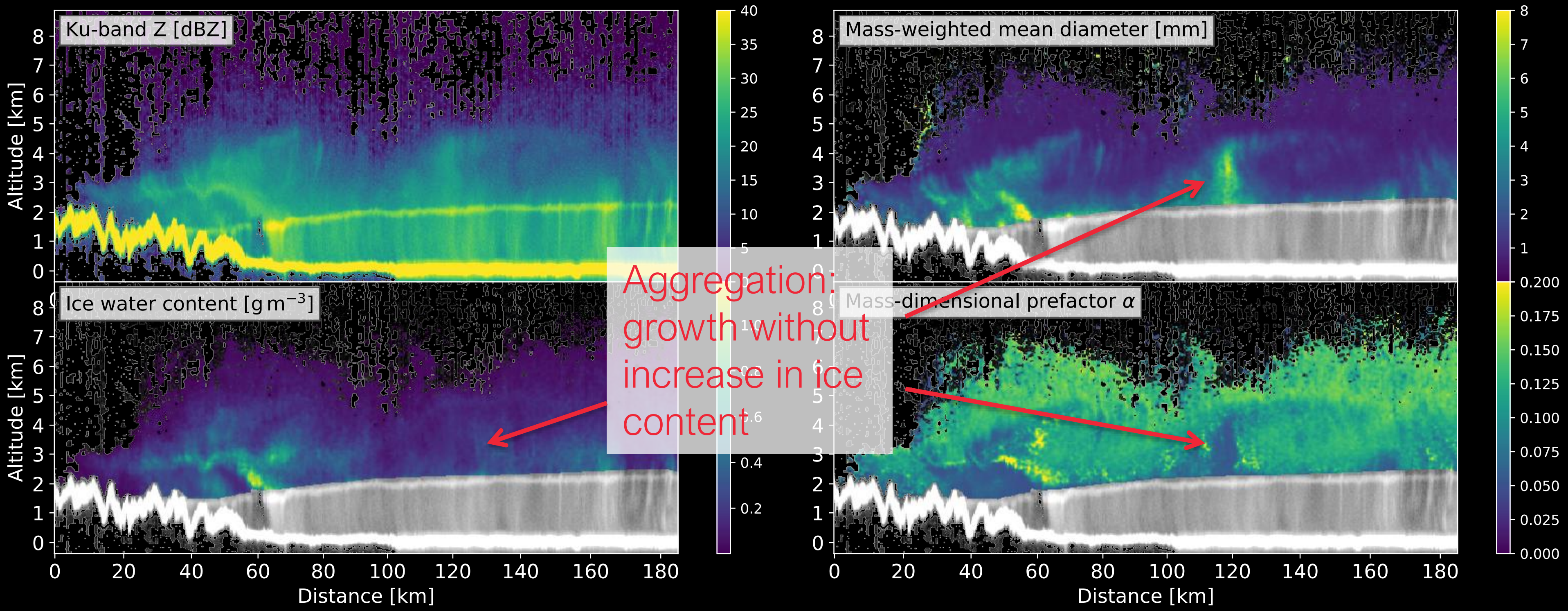
December 1, 2015



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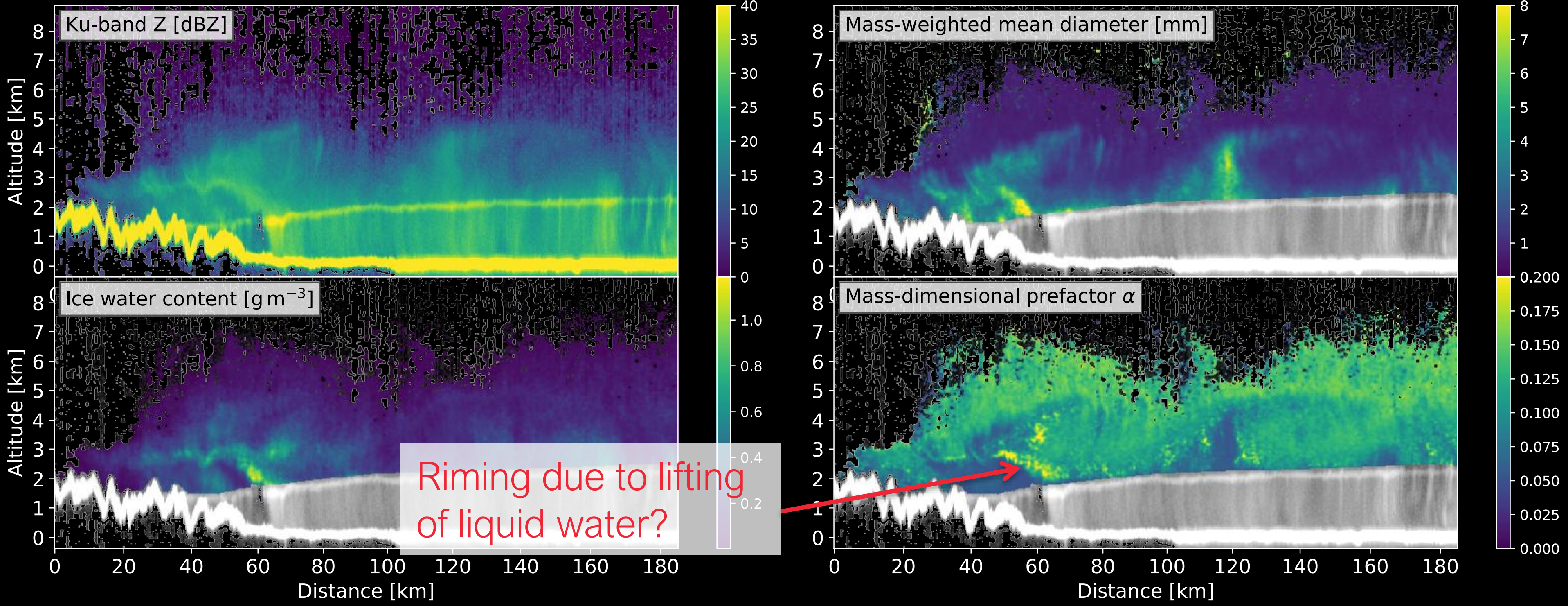

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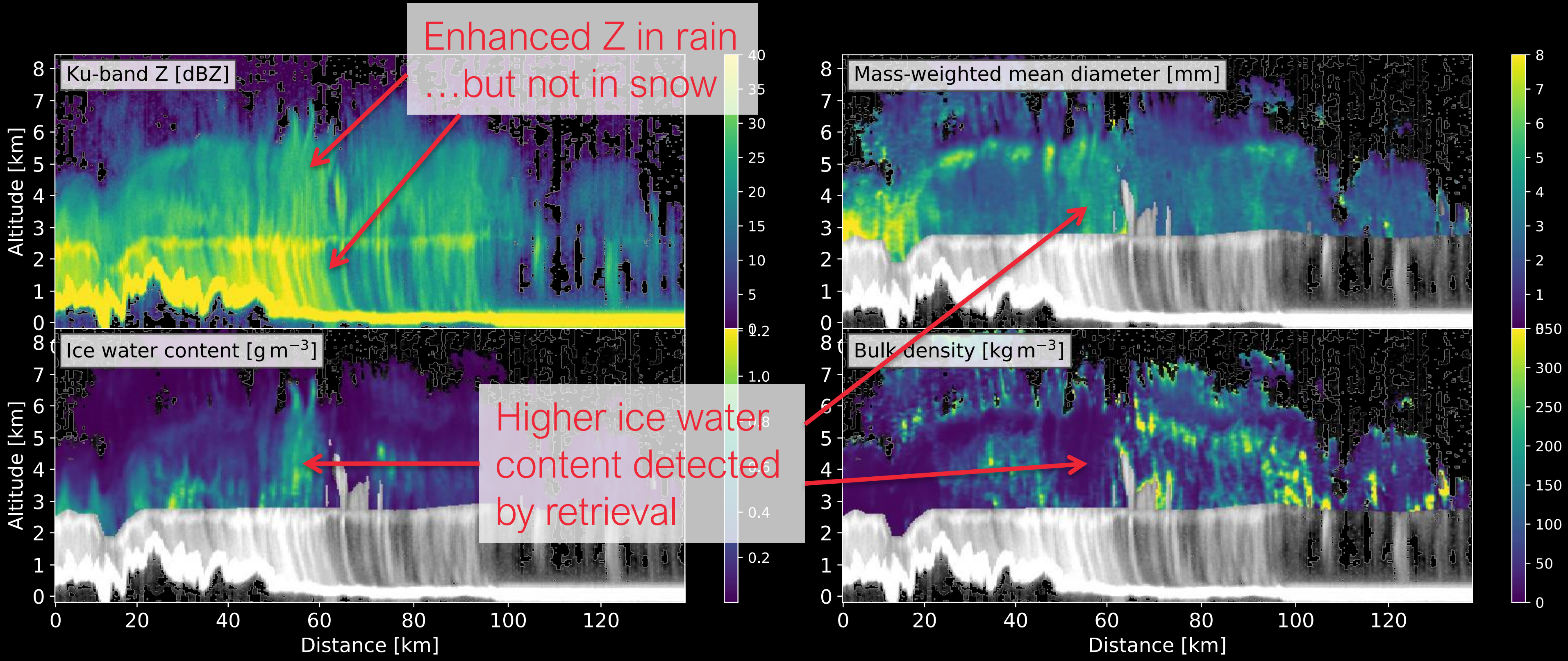

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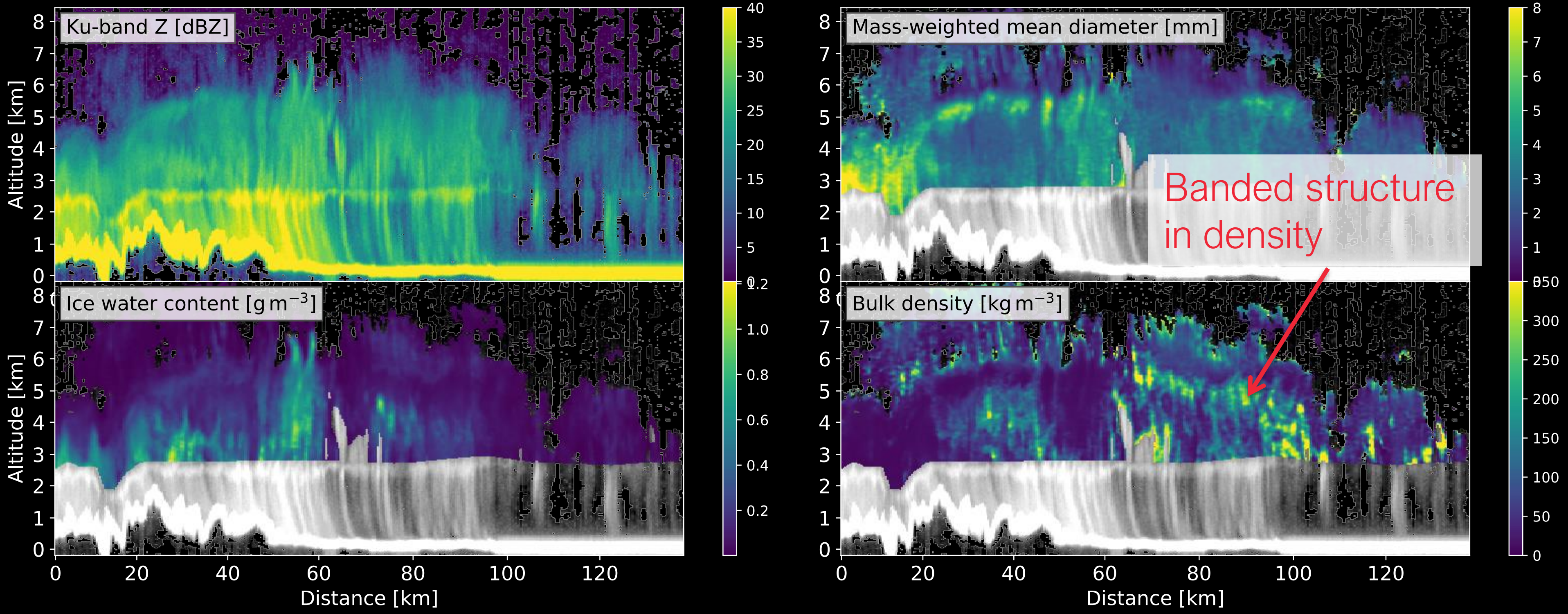

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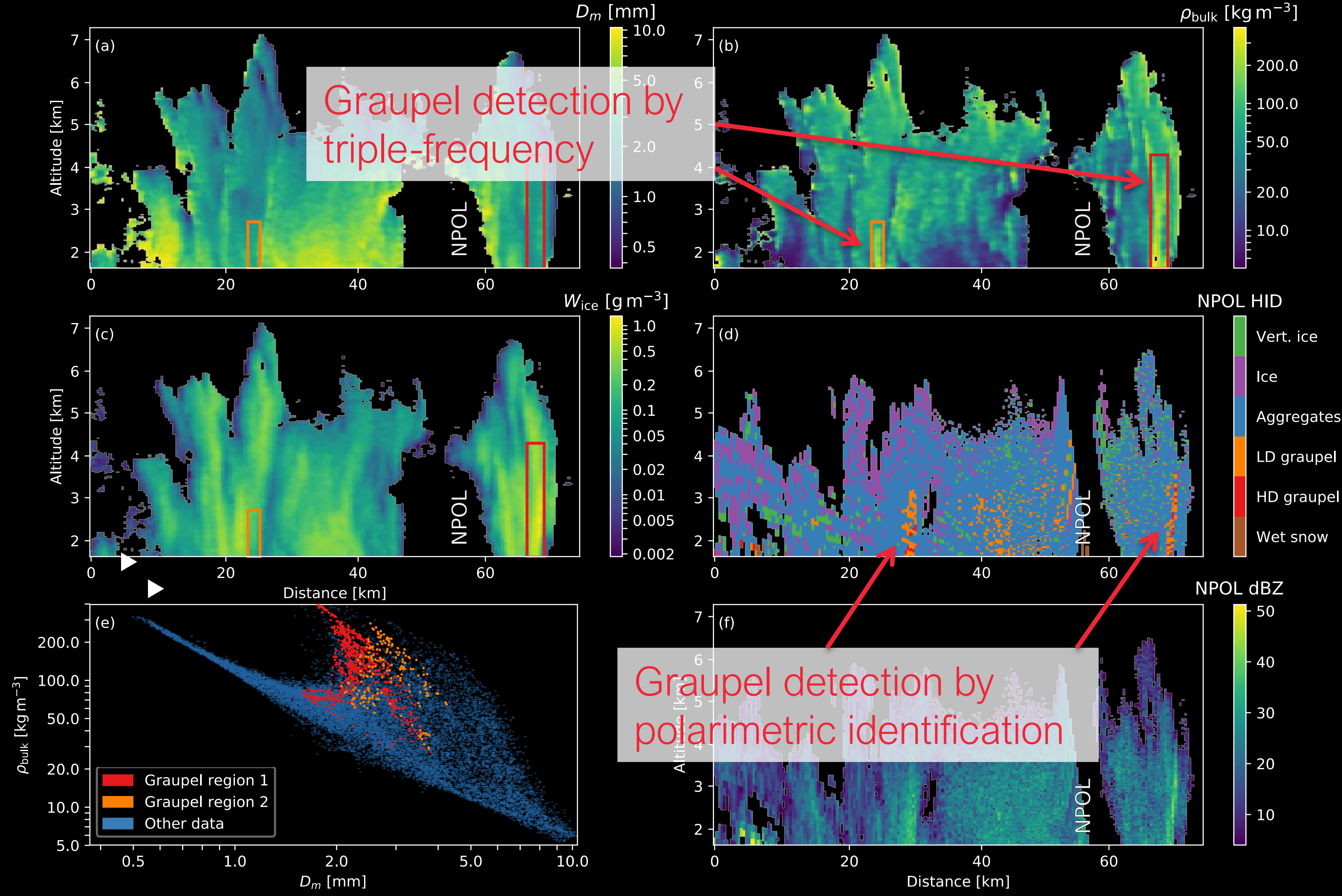


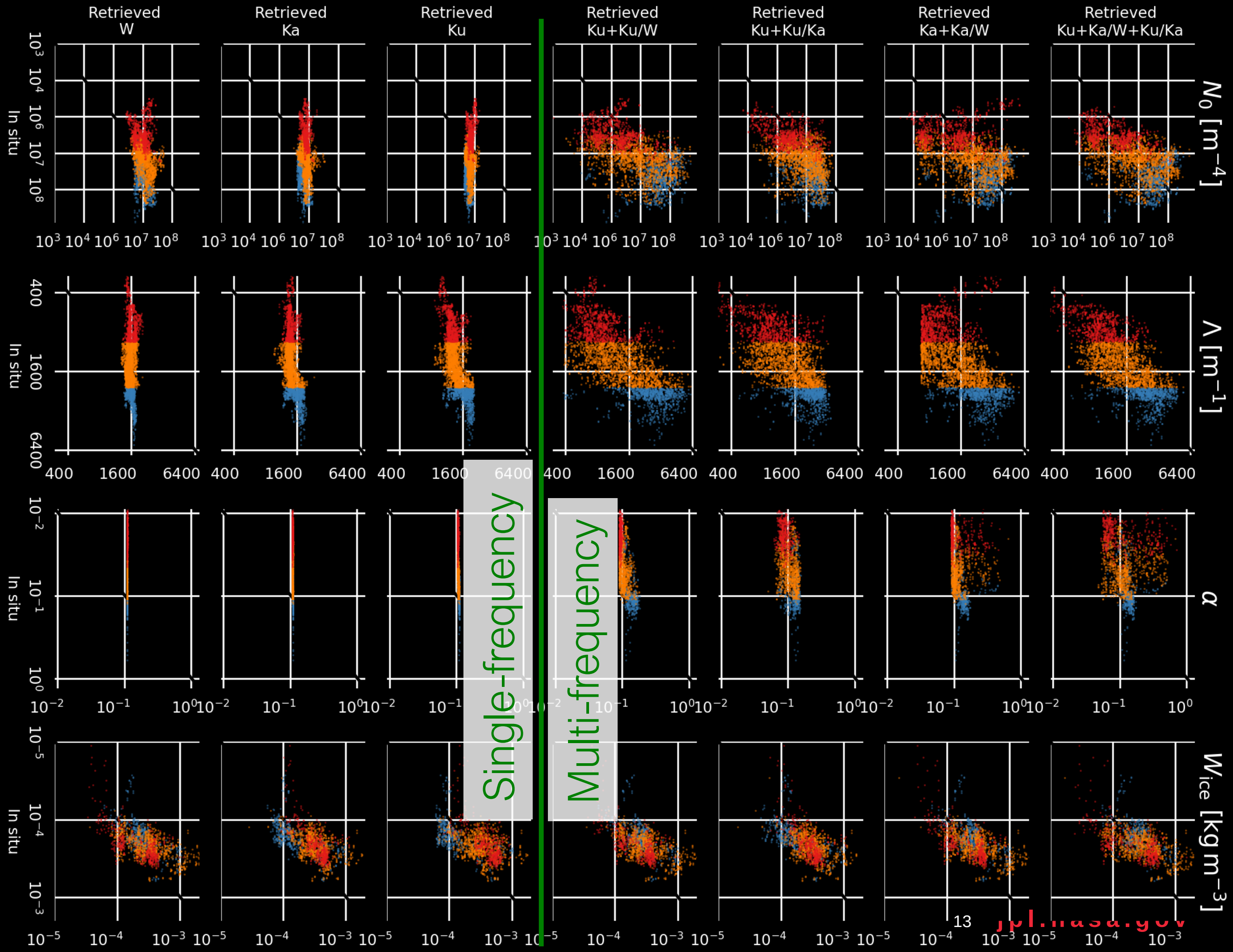
Graupel detection by triple-frequency
Graupel detection by polarimetric identification
(a)
(b)
(c)
(d)
(e)
(f)
D_m [mm]
ρ_{bulk} [kg m^{-3}]
W_{ice} [g m^{-3}]
NPOL HID
NPOL dBZ
Altitude [km]
Distance [km]
NPOL
Vert. ice
Ice
Aggregates
LD graupel
HD graupel
Wet snow
Graupel region 1
Graupel region 2
Other data

Comparisons to in-situ data

Size ▸

Density ▸

Ice water content ▸



Error estimates

- Size and number concentration better constrained by multi-frequency
- Differences in ice water content and density errors are small

	ln N_0	ln Λ	ln α	ln W_{ice}	ln N_T	ln D_m	ln ρ_{bulk}
Ku+Ka/W+Ku/Ka	1.17	0.28	0.70	0.78	1.11	0.27	0.90
Ka+Ka/W	1.24	0.41	0.79	0.80	1.12	0.41	1.10
Ku+Ku/Ka	1.75	0.36	0.76	0.92	1.54	0.35	0.96
Ku+Ku/W	1.10	0.31	0.84	0.79	1.11	0.30	1.08
Ku	2.43	0.58	0.81	1.05	1.92	0.58	1.17
Ka	2.34	0.62	0.81	0.95	1.81	0.61	1.19
W	2.13	0.67	0.82	0.79	1.55	0.67	1.22

Summary

- Multi-frequency retrieval algorithm for ice and snow microphysics
  - Uses snowflake scattering models of varying densities
  - Can identify processes such as aggregation and riming
  - Tested with OLYMPEX airborne 3-frequency radar data
  - Multi-frequency retrievals improve performance for size and number concentration vs. single frequency

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